# RHIC BBA Measurement, Analysis & Related Issues

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# Principle of BBA measurement

If the closed orbit of beam relative to the magnet center of the $i^{th}$ quad located at $s_i$ is $x(s_i)$, then changing the quadrupole strength $k_i$ by $\Delta k_i$ gives beam a deflection angle:

$$\theta_i = \frac{\Delta k_i L_i x(s_i)}{1 + 0.5 k_i L_i \beta(s_i)/\tan(\pi\nu)}$$

where $\nu$ is the tune in the plane under consideration,
$\beta(s_i)$ and $L_i$ are the beta function and length of the quadrupole,
The dispersive corrections of o(1%) are neglected.

The transverse orbit displacement at position s due to deflection $\theta_i$ is:

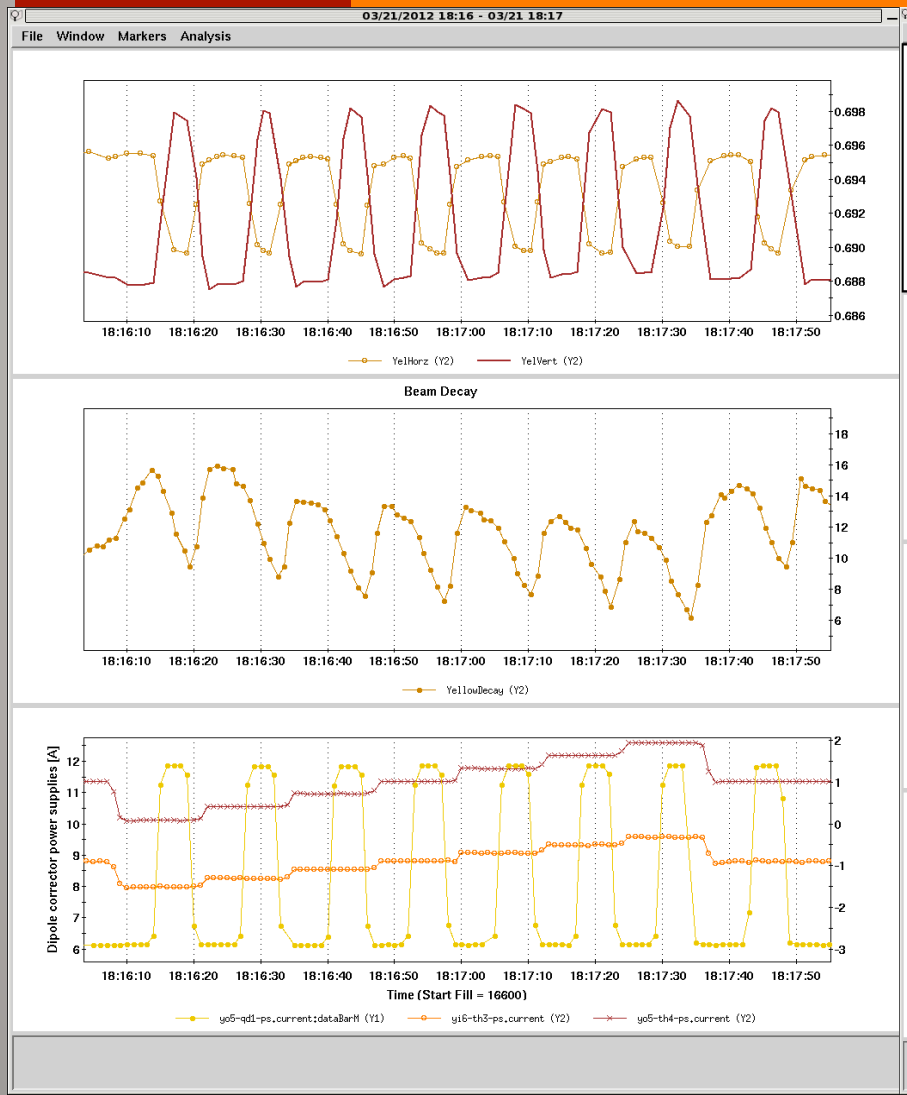
$$\Delta x(s) = \frac{\sqrt{\beta(s)}}{2\sin(\pi\nu)} \sum_{i=1}^{N} \theta_i \sqrt{\beta(s_i)}\ \cos(|\phi(s) - \phi(s_i)| - \pi\nu)$$

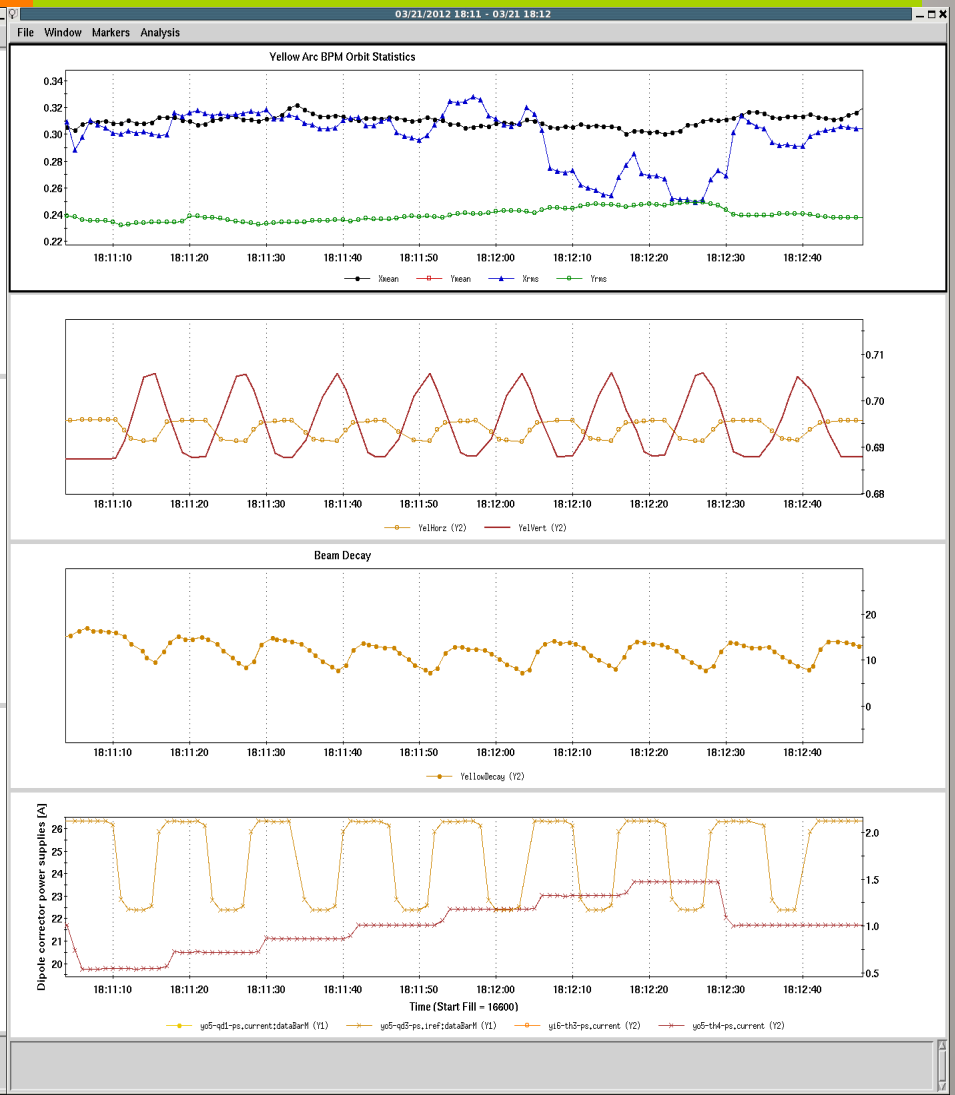
The objective of BBA is to measure the beam offset $x(s_i)$ by steering the beam and minimizing the measured orbit shift associated with changing the quad strength. Then $x(s_i)$ is used to zero the reading of the BPM near by the quadrupole.

Using $\Delta k_i = 2 \times 10^{-3}$ m$^{-2}$ to avoid large optics, tune, and beam lifetime changes. This is 1.7–2.5% of a typical IR quadrupole strength at RHIC injection.

# BBA Measurements (03/21/2012)

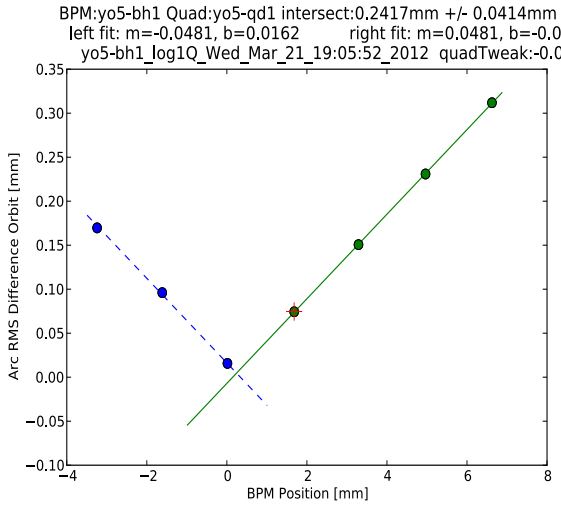
## during two measurements on BPM yo5-bh1

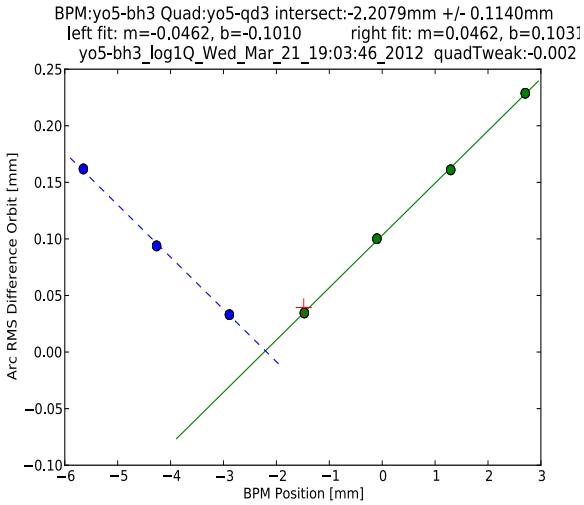


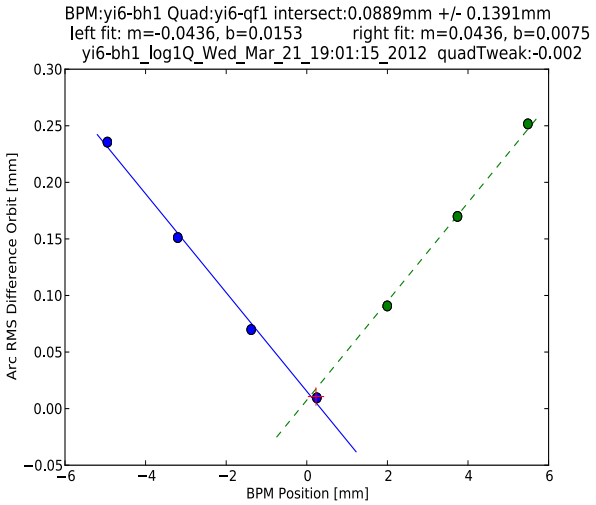



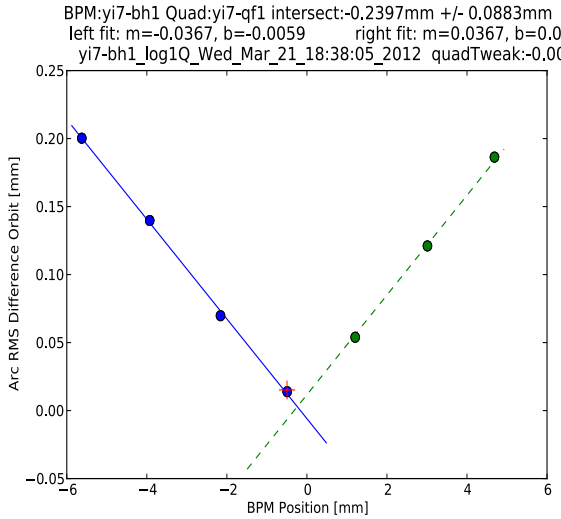
# BBA Analysis of Beam Experiment (03/21/2012)

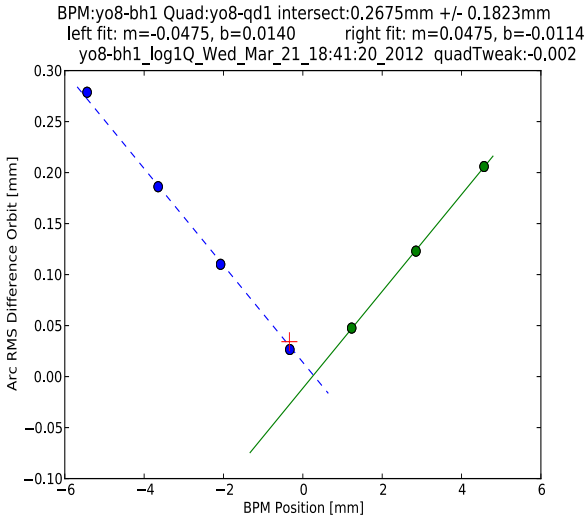
## from 1Hz (all arc) BPM reading

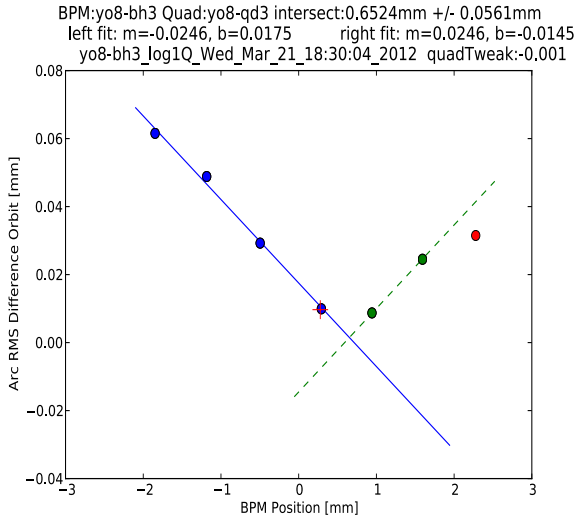


# Results from the BBA Analysis

## from 1Hz BPM reading of all BPMs in all arcs

| | 3/21/2012 | | 3/3/2010 | 3/9/2010 | 3/27/2011 |
|---|---|---|---|---|---|
| BPM | Center (μm) | Error (μm) | (μm) | (μm) | (μm) |
| yo5-bh1 | 242 | +-41 | 220,336 | 135 | 125, 206 |
| yo5-bh3 | -2208 | +-114 | -1784 | -1866 | |
| yi6-bh1 | 89 | +-139 | 200 | 350 | |
| yi7-bh1 | -240 | +-88 | -269 | -264 | |
| yo8-bh1 | 267 | +-182 | | 219 | |
| yo8-bh3 | 652 | +-56 | 457 | 416 | |

# What we have learned from BBA measurement

1. Possible to develop nonconventional procedure to improve the accuracy/speed

   When the machine is reasonably stable BBA measurement can be performed by taking baselines (without changing the quad) for all beam-offset locations, then change quad once and take the measurement at the same set of offset locations. (It allows us to manipulate the offset in a nonconventional fashion in order to improve the accuracy/speed.)

2. A step towards streamline measurement: knowledge on measurement parameters

   A careful choice of beam-offset range and the amount of quad strength change in a given lattice can improve measurement accuracy without much sacrifice of beam lost. It was found the best beam-offset range is [-3.0 3.0]mm with quad strength change of -0.002 on Q1 or Q2 at injection.

3. A step towards automatic analysis: data requirement for reliable analysis

   Needs minimum 9 measurement points (4 on positive side and 4 on the negative side) to have confidence of good measurement since a line obtained from fitting 2 or 3 measurement points appears to be unreliable.

4. Knowledge on measurement accuracy vs. 1Hz BPM reading settle time

   The 3 seconds waiting time for the 1Hz BPM reading appears to be adequate. But the first/last measurement point (after a big step from/to the original setting) is bad in some of the measurements. The solution could be a 4-5 seconds waiting for the first and the last step.

# Issues Related to BBA Measurement in RHIC

**Why is BBA Measurement Difficult in RHIC**

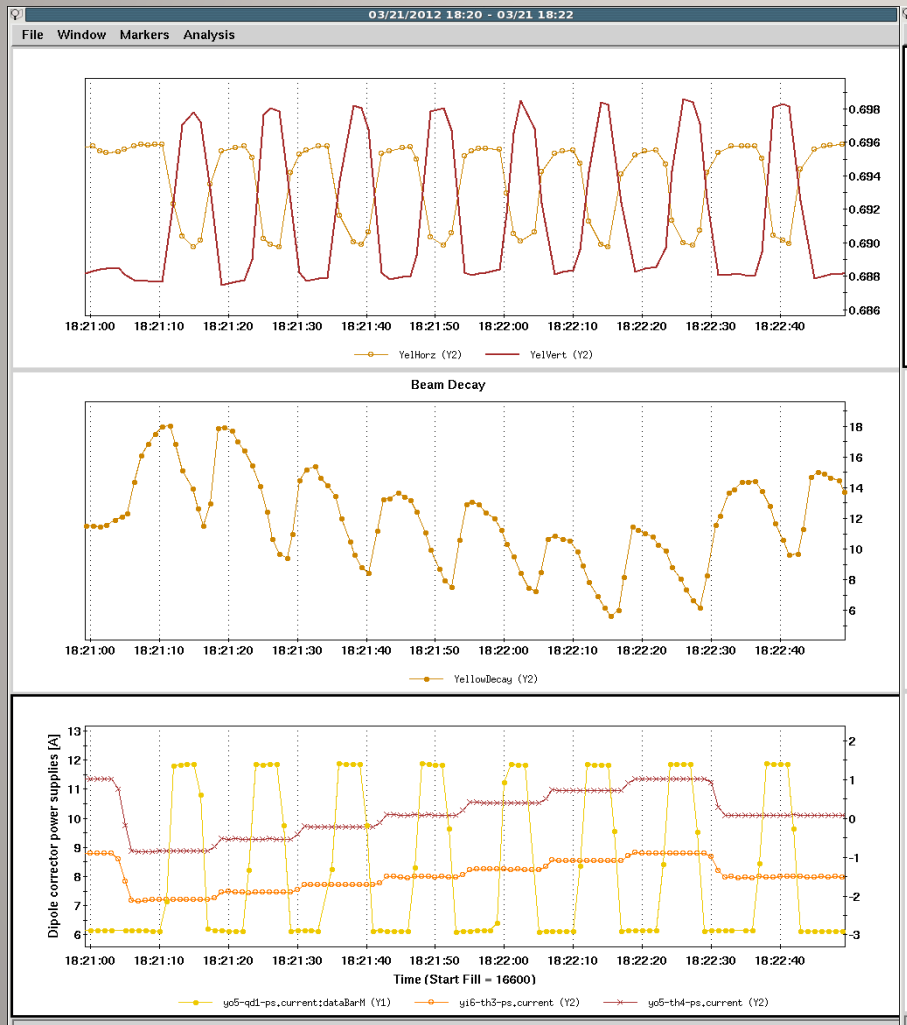
1. Limited dipole correctors.
2. Very large ring. When all the BPMs in all arcs are used, some BPMs contribute to noise ore than to signal.
3. Signal/Noise ratio is low.

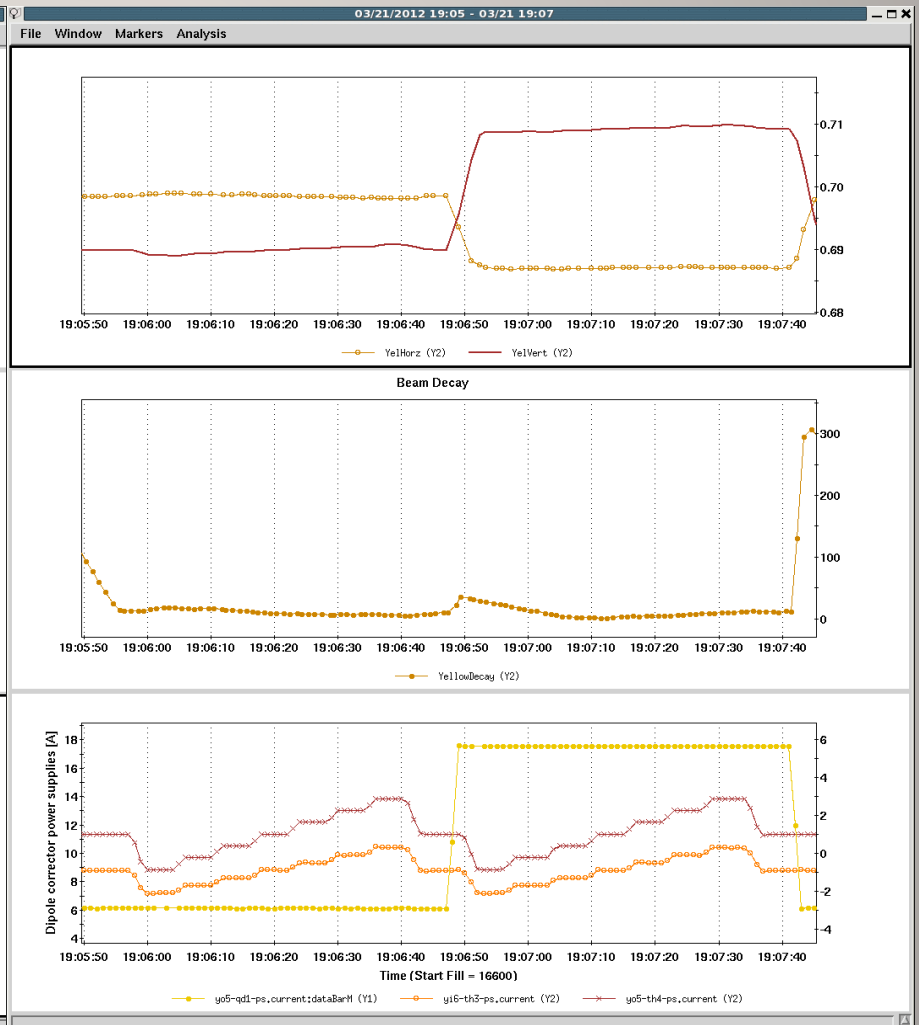
**Why is BBA Measurement Difficult in RHIC**

1. Step-by-step (faster easier procedure).
2. Chose subgroup of BPMs.
3. Minimize the frequency of quadrupole change. (Procedure with 1-Q-Move)

# BBA Measurements (03/21/2012)

## traditional procedure vs. 1-Q-move procedure

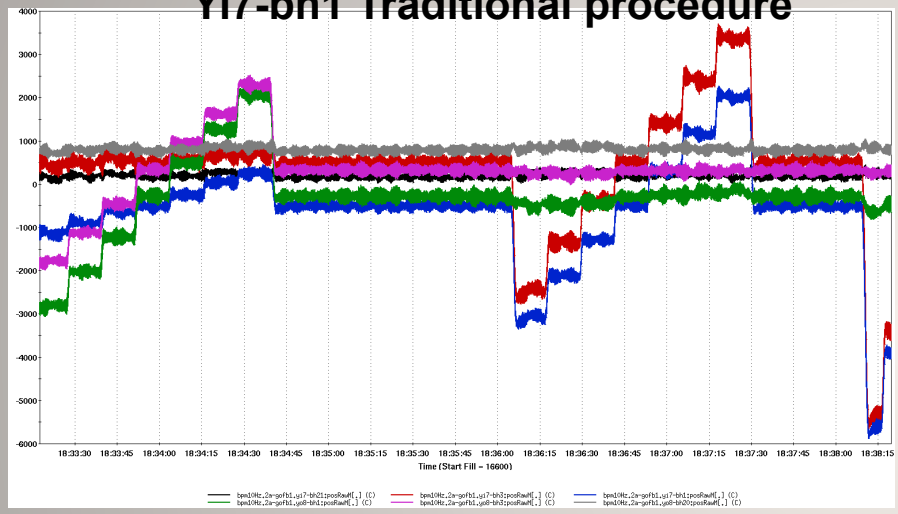


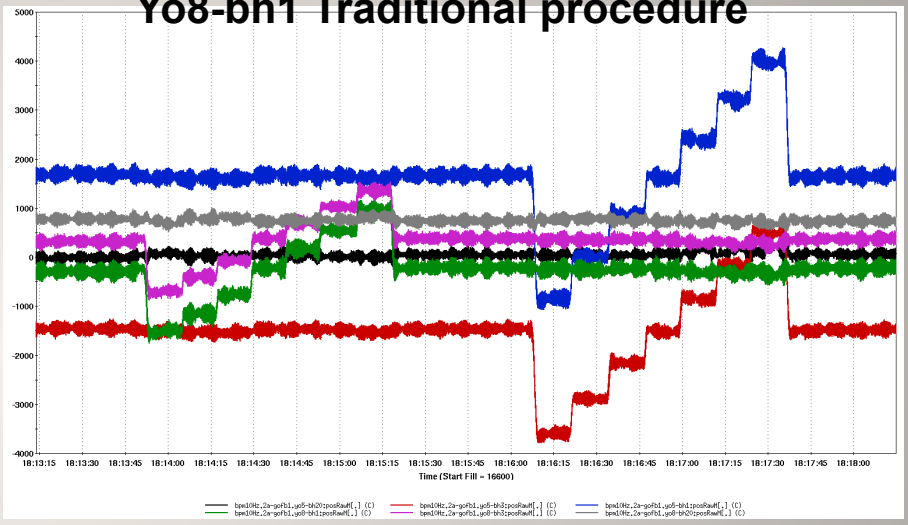
# Beam Experiment (03/21/2012)

## 1kHz signals on BPM 1kHz signals on BPM in yi7 & yo8 during yi7-bh1 & yo8-bh1 measurement

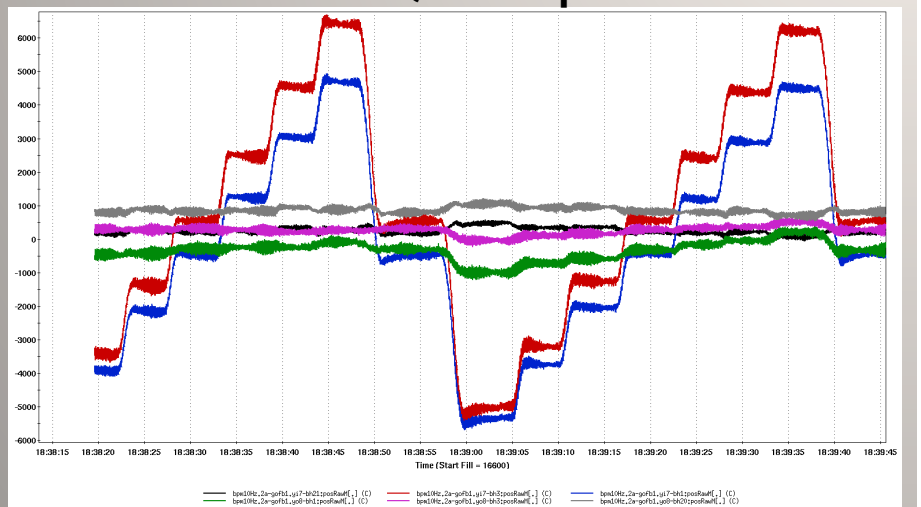
### Yi7-bh1 Traditional procedure



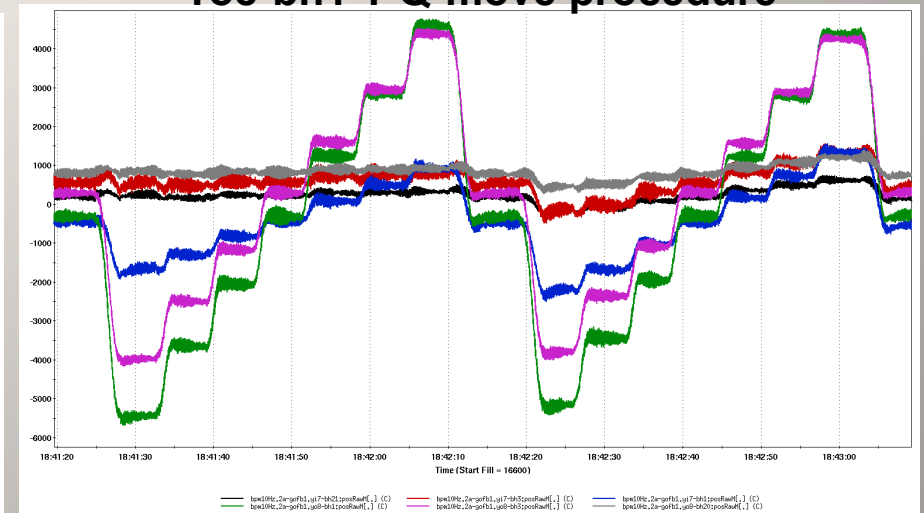

### Yo8-bh1 Traditional procedure




### Yi7-bh1 1-Q-move procedure




### Yo8-bh1 1-Q-move procedure



# Beam Experiment (03/21/2012)

## 1kHz signals on BPM in yi2, yi3, yo4 during yo5-bh1 measurement